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MSC Protocol for Target Coverage Issue in Wireless Sensor Networks

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Abstract— **Wireless sensor networks are energy constrained networks which is equipped with a battery which has limited lifetime. Replacing the battery regularly is not a feasible option and is quite expensive since a sensor network is comprised of many nodes and replacing several nodes involves high maintenance cost. Thus effective sensor scheduling and power management is a vital requirement which will optimize the lifetime of the sensor network. In this paper we analyze the sensor scheduling and target coverage issue in sensor networks and propose a new technique which can optimize the placement of sensor nodes into a monitored area and their organization so that the full coverage is achieved with minimal energy consumption. Specifically, we have developed a heuristic that organizes the available sensor nodes into mutually exclusive sets where the members of each of those sets completely cover the monitored area.**

Keywords-Wireless Sensor Network; Coverage; Distributed Networks; Communication; MSC Protocol.

I. INTRODUCTION

In our daily lives we are constantly surrounded by thousand of wireless networks, and in the last years, the number of those networks related with sensors has been increasing. Such networks are often deployed in resource-constrained environments, for instance with battery powered nodes running untethered. Advances in wireless communication made it possible to develop wireless sensor networks (WSN) consisting of small devices, which collect information by cooperating with each other. These small sensing devices are called nodes and consist of CPU (for data processing), memory (for data storage), battery (for energy) and transceiver (for receiving and sending signals or data from one node to another). The size of each sensor node varies with applications.[1] For example, in some military or surveillance applications it might be microscopically small. Its cost depends on its parameters like memory size, processing speed and battery [1]. Today, wireless sensor networks are widely used in the commercial and industrial areas such as for e.g. environmental monitoring, habitat monitoring, healthcare, process monitoring and surveillance. For example, in a military area, we can use wireless sensor networks to monitor an activity. If an event is triggered, these sensor nodes sense it and send the information to the base station (called sink) by communicating with other nodes. The use of wireless sensor networks is increasing day by day and at the same time it faces the problem of energy constraints in terms of limited battery lifetime.

In wireless sensor network one most critical issue is the network lifetime. Sensing, communications consume energy.[2] Since replacing the battery is not feasible in many applications, low power consumption is one of the most important requirements of a sensor network. Therefore judicious power management and sensor scheduling can effectively extend network lifetime. Sensor nodes are small devices equipped with one or more sensors, one or more transceivers, processing, storage resources and possible actuators. Sensors nodes organize in the networks and collaborate to accomplish a larger sensing task. The characteristics of the sensor network include limited resources, large and dense networks (of hundreds or even thousands of sensor nodes) and a dynamic topology. A sensor node's radio can be any one of the following four state: transmitting, receive, idle, or sleep. The transmit state is when the sensor node transfer the sensed data, the receive state is when the sensor node receive the sensed data, the idle state is when the receiver is neither transmitting nor receiving, and the sleep mode is when the radio is turned off. The source of energy for a node is most often an attached battery cell. Since the size of a cell is limited, the amount of available energy is also limited. Therefore, sensor network architectures and applications, as well as deployment strategies, must be developed with low energy consumption as one of the important requirements. [4]We study the problem of the placement of sensor nodes into a monitored area and their organization so that the full coverage is achieved with minimal energy consumption. Specifically, we have developed a heuristic that organizes the available sensor nodes into mutually exclusive sets where the members of each of those sets completely cover the monitored area. Only one such set is active and consumes power at any moment. After a specified interval another set is activated, while the first one is deactivated. In one round all sets are used, and then the whole process repeats until the sensors are out of power. The lifetime of the whole system directly corresponds to the number of allocated sets; therefore, the goal of the algorithm is to maximize the number of the sets. The first phase of the algorithm determines how many different sensor nodes cover the different parts of the monitored area. The second phase allocates sensor nodes into mutually independent sets [7].

II. TARGET COVERAGE PROBLEM

In target coverage problem [3] our main objective is to cover a set of points or targets. We consider a number of targets with known locations that need to be observed or covered and a large number of sensors randomly deployed closed to the targets. We also consider a central data collector node, which will refer as the base station (BS) [5][6].

Definition 1: Target Coverage Problem (TCP): Given m targets with known location and energy constrained wireless sensor network with n sensors randomly deployed in the targets' vicinity, schedule the sensor nodes activity such that all the targets are continuously observed and network lifetime is maximized. As the number of sensor deployed in the field is generally larger than the optimum needed to perform the required task, an important energy efficient method consist in scheduling the sensor nodes activity to alternate between active and sleep state. We consider that a sensor node radio can go the sleep mode when the node is not scheduled to perform the sensing task. There are m number of targets with known location and an energy constrained wireless sensor network with n number of sensors randomly deployed in the closed proximity of the targets, scheduled the sensor nodes activity such that all the targets are continuously observed and network lifetime is maximized[10].

The sensor scheduling mechanism can be accomplished as follows:

• *Sensors send their location information to the BS.*

• *BS executes the sensor scheduling algorithm and broadcasts the schedule when each node is active.*

• *Every sensor schedules itself for active/sleep intervals.*

In this section we concentrate with designing the node scheduling mechanism and do not address the problem of selecting which protocol is used for data gathering or node synchronization.

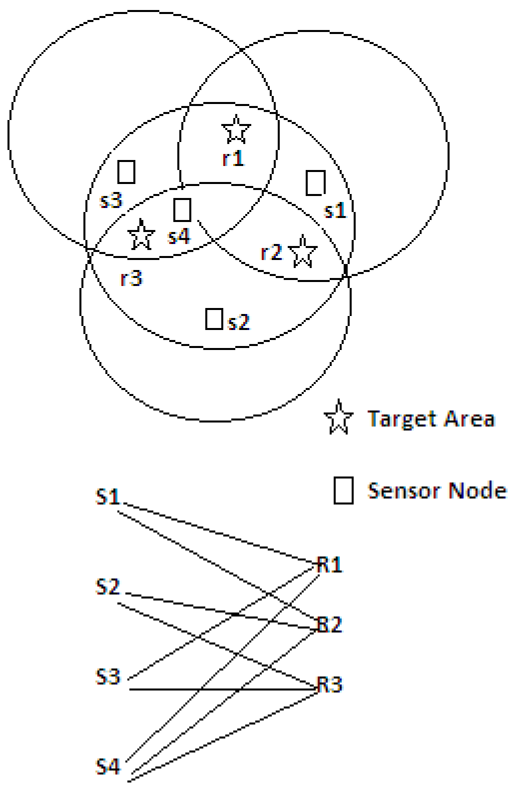

Figure 1. Example with 3 targets and 4 sensors

III. MAXIMUM SET COVERS PROBLEM:[8][9]

Let us assume that there are n number of sensors such as *s*1,*s*2,..*sn* are randomly deployed to cover m number of targets such as *r*1,*r*2,..,*rm*. The BS has coordinates of the sensor nodes and the targets, therefore it is able to compute for each sensor nodes which targets it covers. One method is to cover a target if the Euclidean distance between sensors and the target is smaller or equal to sensing range.If (*x*1,*y*1) is the point of the sensor and (*x*2,*y*2) is the point of the targets and *Rc* is sensing range. Figure 1shows an example with 4 sensing nodes *s*1,*s*2,*s*3,*s*4 and 3 targets *r*1,*r*2,*r*3.We assume a node sensing area being the disk centered at the sensor with radius equal to sensing range. Figure 2 shows the coverage relationship between sensors and targets that are *s*1={*r*1,*r*2}, *s*2={*r*2,*r*3},*s*3={*r*3,*r*1},*s*4={*r*1,*r*2,*r*3}. we assume that all sensor node have the same remaining time. Each sensor can be active for unit time of 1 that is if all sensor are active continuously then the network lifetime is 1. Here we improves the scheduling scheme by allowing every sensor to be part of more than one set and by allowing the set to be operational for difference time interval. In the above figure set covers are *S*1={*s*1,*s*2} for 0.5 time, *S*2={*s*2,*s*3} for 0.5 time, *S*3={*s*1,*s*3} for 0.5 time, *S*4={*s*4} for 1 time activated. Thus the total network lifetime is 2.5.

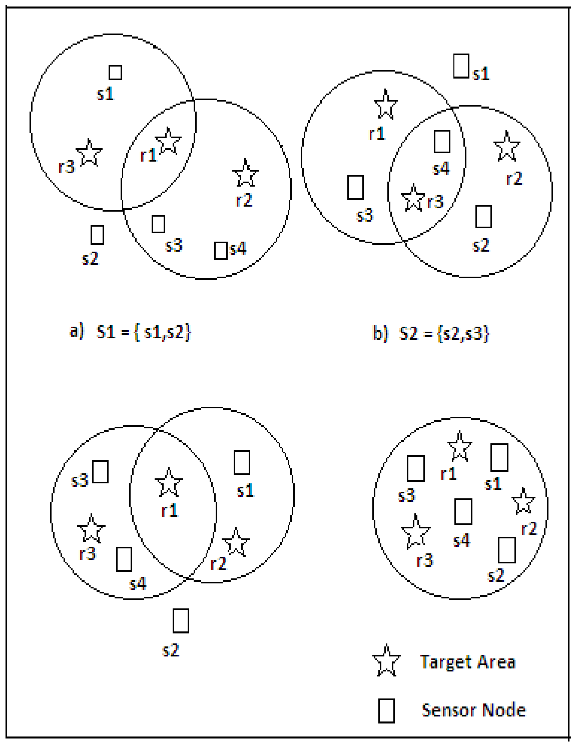

Figure 2. Four Cover sets

Definition 2: Maximum Set Cover Problem: Given a collection C of subsets of a finite set R, find a family of set covers *S*1,....,*Sp* with time weight *t*1,....,*tp* in [0,1] such that to maximize *t*1+*t*2+...+*tp* and for each subset s in C, s appears in *S*1,..,*sp* with total weight of at most 1,where 1 is the life time time of each sensor. In MCS definition, C is the set of sensors and R is the set of targets, such that each sensor cover a subset of targets. We want to determine a number of set covers *S*1,*S*2,...,*Sp*, where each set cover *Si*, i,...p completely covers all the targets, such that to maximize the network lifetime *t*1+*t*2+...+*tp*, where *tj*,j=1,..p is the time interval while the set cover *Sj* is active.

In this section we present a heuristic technique for the MSC problem. We propose a Greedy heuristic in where set cover are formed individually by covering most critical targets

A. Greedy-MSC Heuristic:

Here we propose a greedy approach for the MSC problem. Our heuristic takes the input parameters C-the set of sensors, R-the set of targets, and w-sensor lifetime granularity, w∈(0,1]. The heuristic returns i-the number of set covers and the set covers $C1,C2,...,Ci$.

Algorithm

Greedy-MSC Heuristics(C,R,w)

1. set the lifetime of each sensor to 1
2. SENSORS=C
3.i=0
4. while each target is covered by at least one sensor in SENSORS do
5. i=i+1
6. Ci=∅
7. TARGETS=R
8. while TARGET≠∅ do
9. find a critical target rcritical∈TARGETS
10. select a sensor su∈ SENSORS with greatest contribution, that covers rcritical
11. Ci=Ci ∪ su
12. for all targets rk∈ TARGETS do
13. if rk is covered by su then
14. TARGETS=TARGETS-rk
15. end if
16. end for
17. end while
18. for all sensors sj∈ Ci do
19. lifetime-sj = lifetime-sj - w
20. if lifetime-sj == 0 then
21. SENSORS=SENSORS-sj
22. end if
23. end for
24.end while
25.return i-number of set covers and the set covers C1,C2,...,Ci

B. Critical Target:

The target most sparsely covered, both in terms of number of sensor as well as with regard to the residual energy of those sensors is called critical target. Once the critical target has been selected the heuristic selects the sensor with the greatest contribution that covers the critical target. For example we can consider a sensor to have greater contribution if it covers a large number of uncover target and if it has no residual energy available. We use w to represent the time that each set cover is active. For example, for w=0.25, each sensor can be part of at most 4 set coverand for w=1 means the disjoint set cover.

IV. CONCLUSION

Wireless sensor network are battery powered, therefore prolonging the network lifetime through a power aware node organization is highly desirable. An efficient method for energy saving is to schedule the sensor node activity such that every sensor alternate between sleep and active state. One solution is to organize the sensor node in set covers, such that every cover completely monitors all the targets. These covers are activated in tern such that at a specific time only one sensor set is responsible for sensing the target, while all other sensors are in sleep state. This problem is modeled as maximum set cover problem.

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